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Experiments with Gap Detection

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EXPERIMENTS WITH GAP DETECTION

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Abstract

Test procedures and signals used by different research groups are described. Results from a comparison of two procedures, three-alternative forced-choice and Békésy, are reported. The characteristics of the test signal and the masker are discussed.

INTRODUCTION

Gap Detection is a method for measuring the time resolution of the ear. A noise segment with a gap of a certain length is presented to the listener. The task of the subject is to detect the gap. If the he/she can do this, noise with a shorter gap is presented but if he/she cannot detect the gap, it is lengthened. A Gap Detection threshold is then determined with an up-down method (Levitt, 1971).

Gap Detection has been used extensively both in research and clinically. However, there has been no consistency in the choice of stimuli and procedure.

There are several different test procedures. The three principal ones are: two-alternative forced-choice, 2AFC (Glasberg & Moore, 1989; Shailer & Moore, 1983), three-alternative forced-choice, 3AFC (Tyler, Summerfield, Wood, & Fernandes, 1982) and adjustment of the signal-to-noise ratio to a determined gap length by use of a Békésy technique (Fitzgibbons, 1983; 1984; Fitzgibbons & Gordon-Salant, 1987).

The differences are greater in the use of stimuli. Some researchers use broad-band noise while those who want to make a frequency-specific measurement filter the noise in some way. Mostly some kind of band-limited noise has been used but high-pass and low-pass filtered noise have also been applied. There have been many different centre frequencies and bandwidths. The filter slopes are almost always very steep (96 dB/octave). With this kind of filter it has been necessary to add a masker. The masker is most often notch-filtered with the same filter characteristics as for the signal and presented at 20 dB below it.

METHOD

Procedure

The two procedures we wanted to compare were 3AFC and a Békésy technique where the length of the gap was adjusted according to the listener's response. The test using 3AFC was a program under DOS and had been used a lot (more than 200 patients). The other test was a completely new Windows program.

In the 3AFC test, three noise bursts separated by one second are presented to the listener. One of them contains a gap. The task of the listener is to decide in which segment the gap is located.

In the Békésy test, a continuous noise is presented and at regular intervals there is a gap. The task is to detect the gap and answer by holding down or releasing a button. The length of the gap is changed in steps of 1 ms.

Stimuli

The stimuli for both tests consisted of one octave wide noise bands with centre frequencies of 500 Hz, 1000 Hz, and 2800 Hz. No masker was added since the filter slopes were not very steep (18 dB/octave) and no splatter was audible or visible in the spectrogram.

For the first test, 3AFC, each segment of one second started and ended with a 2 ms raised cosine slope (Fig. 1). These segments were stored in files while the stimuli for the Békésy test were generated in real time. The gaps in both tests started and ended by a 2 ms slope. The length of the gap was defined as the duration at half the amplitude.

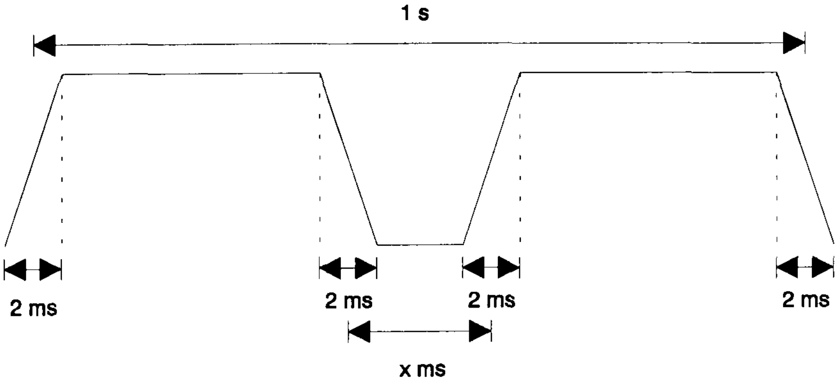

Fig. 1. The shape of a noise segment.

Subjects

Five normal-hearing listeners participated in the gap detection test. The subjects were tested monaurally at a comfortable level (about 50 dB above threshold determined for the tested signal). The same ear was tested at the same level for both procedures. They also ranked the tests according to how comfortable they felt performing it.

RESULTS

The results from two test procedures are approximately the same (Fig. 2). Differences in the score for the two tests could be due to the order in which the tests are performed, the task or the resolution of each test.

Every subject was tested starting with the 3AFC procedure and noise with a centre frequency of 500 Hz. All frequencies were tested before changing to the other test procedure. This might give some training for the Békésy test.

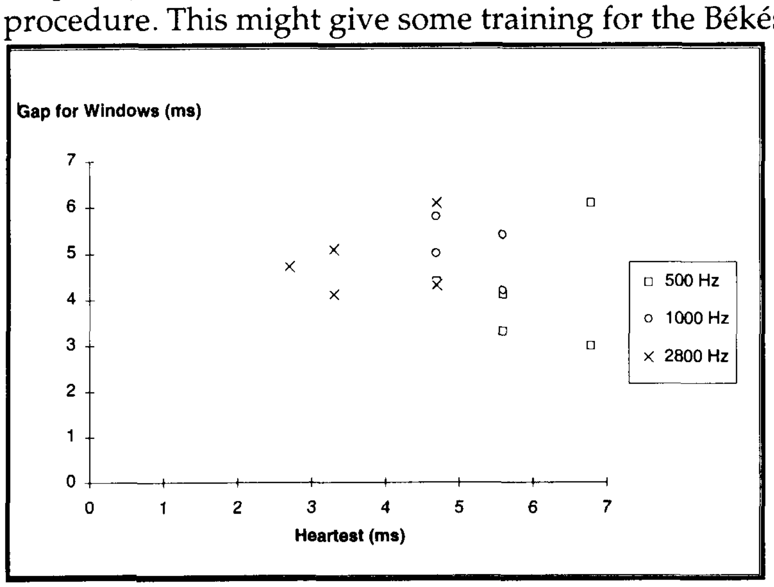

Fig. 2. Comparison of Gap thresholds.

For the 3AFC procedure, the task is to discriminate between a stimulus containing a gap and one without a gap while the task for the Békésy test is to detect a gap. Just detecting a difference between two noise segments does not necessarily mean that the gap is detected. It could be a frequency change that is detected.

Heartest gives a score rounded up to the closest matching step. Any value in between these steps (2.2, 2.7, 3.3, 3.9, 4.7 ms etc.) gives the same result. The results for the Békésy test are rounded to one decimal. Scores in a certain area in the chart could be considered to be the same.

Differences in the results might also depend upon the stimuli. The results from the Békésy test seem to depend a little less on the centre frequency of the noise band.

A closer look at the spectrograms of the two signals revealed that the noise for the Békésy test (Fig. 3) contained more energy in the higher frequencies than the noise for the 3AFC test (Fig. 4). This might account for the insensitivity to the centre frequency for the Békésy test. The higher frequency could be the one that determines the gap threshold. This idea conforms with the suggestion that the temporal response of the auditory filter may limit gap detection at low frequencies (Shailer & Moore, 1983).

The subjects all felt that the Békésy procedure was a little more stressful than the 3AFC procedure. However, most of them liked it because of its speed.

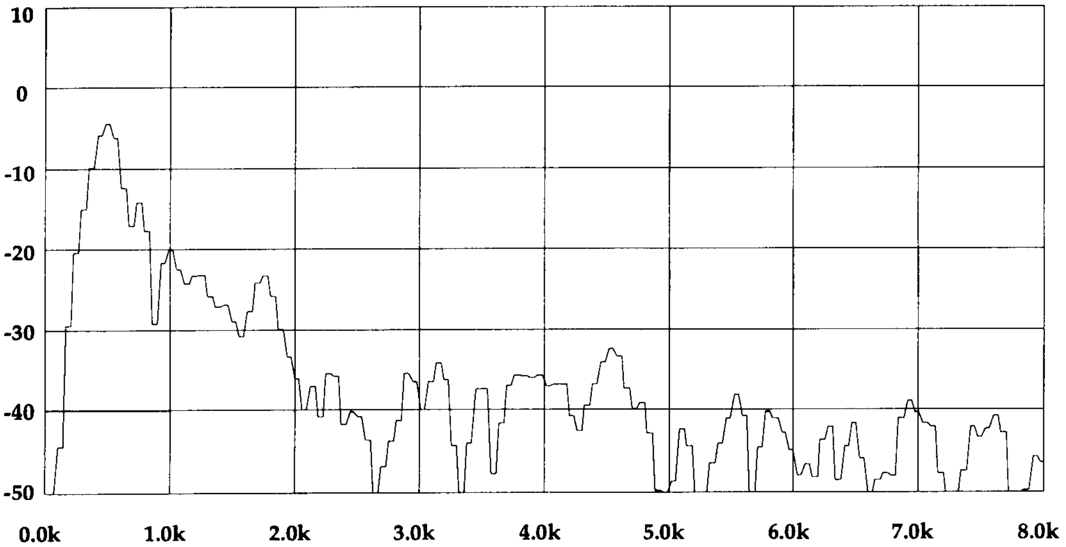

Fig. 3. Spectrum section for the noise used in the Békésy test.

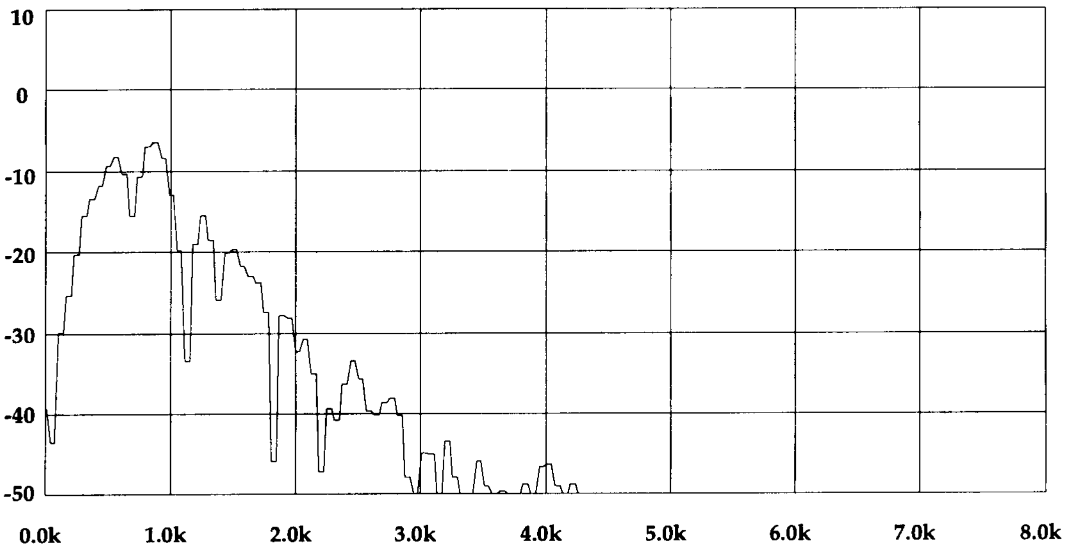

Fig. 4. Spectrum section for the noise used in the 3AFC test.

DISCUSSION

Since every gap in the time domain provokes a splatter in the frequency domain, special care has to be taken when using filters with steep slopes. The use of a masker is dubious because that would affect the adjustment of the tested level (Fig. 5). Subjects with different hearing impairments would perceive the stimulus differently.

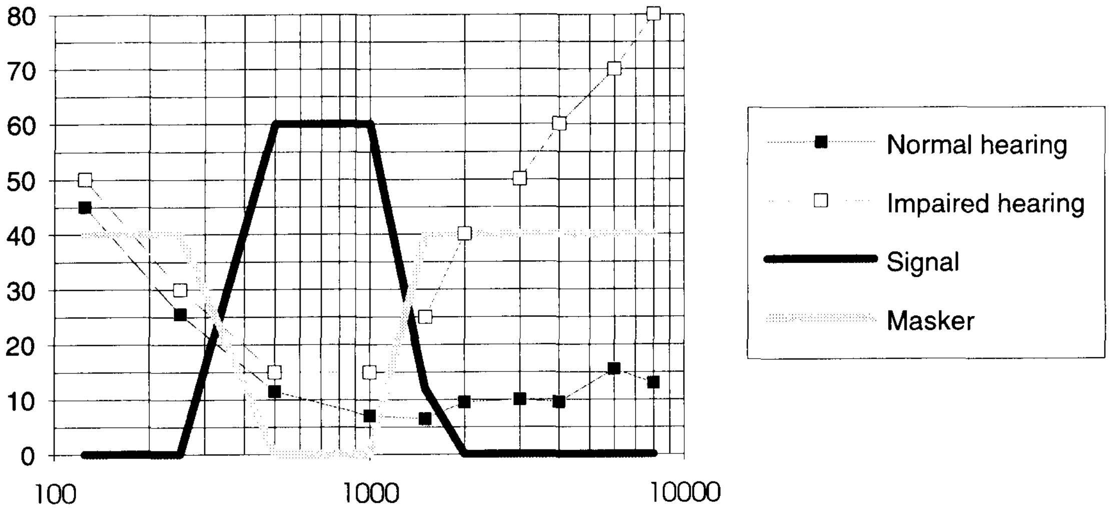

Fig. 5. The effect of a notch filtered masker.

If there is a pattern in the sample files used by the 3AFC test, the listener can learn to recognise it. He/she will then pass the test not by distinguishing the gap but by determining which two segments are alike.

Another similar source of errors is the possibility of an abnormality in the files, e.g., a click, which can be confused with the gap. When using noise created in real time, this kind of error will not repeat itself.

A way dealing with the problem of frequency splatter would be to construct the noise segments, including the one containing no gap, of two halves (De Filippo & Black Snell, 1986). When using the 2AFC and 3AFC procedures, this would make it impossible to distinguish the segment containing the gap by listening to the frequency splatter since it is present in all alternatives.

DESCRIPTION OF THE WINDOWS PROGRAM

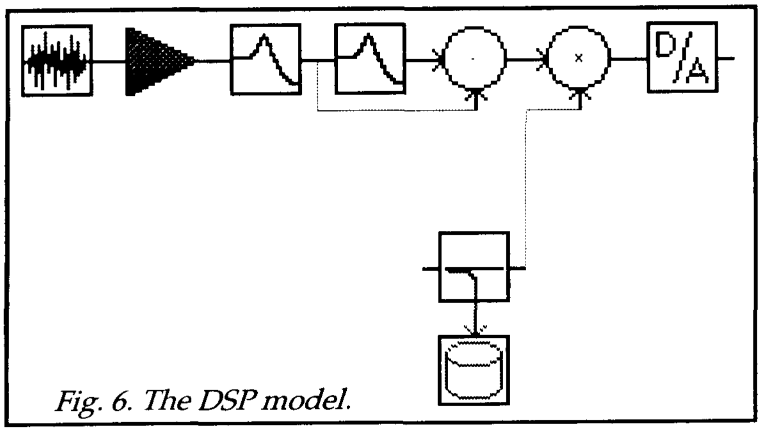

Fig. 6. The DSP model.

The DSP program

A graphical editor in Windows, Aladdin (Neovius & Ternström, 1992), was used to create the model of the program for the DSP (Fig. 6). The Aladdin program then generated a list of messages. This sequence of messages is used to set up a DSP program that generates the stimuli. Noise is created, amplified, filtered and multiplied with samples transmitted from the host computer.

The host program

The host program was written in Microsoft C++ for Windows. Its main functions are to handle the administration of a test, take care of user input, control the DSP model and compute and display the results (Fig. 7).

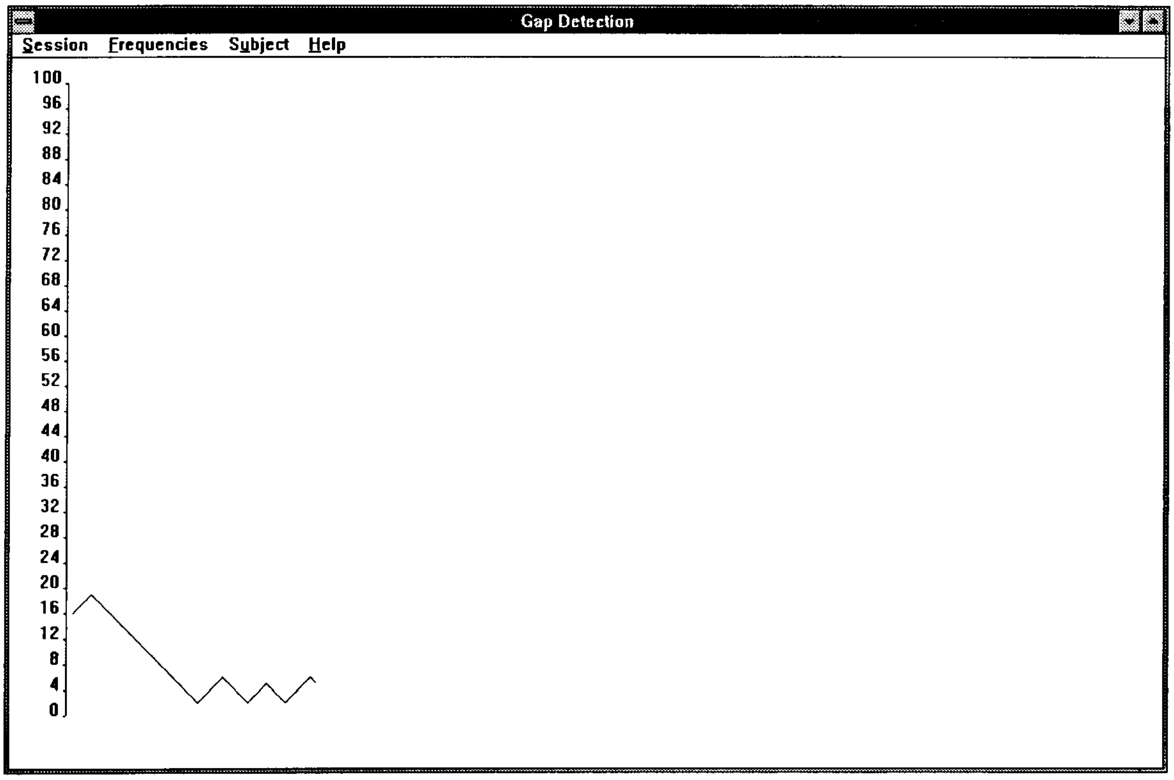

Fig. 7. The Windows program.

The model is controlled in two ways. The first is by sending messages to objects in the model, such as the filters, to set frequencies, bandwidths, etc. The other is by transmitting a waveform to it through the data duct. The waveform consists of a high level followed by a negative raised cosine ramp, a low level, a positive raised cosine ramp and another high level. It is multiplied with the filtered noise to form the test signal. The duration of a cycle is one second and each ramp is two ms long.

Because of the hardware, an Ariel DSP 16 board was used, each cycle was divided into 16 segments each forming one queue. The user response is given through the mouse and according to it, the two middle queues are modified to change the size of the gap.

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